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SEVAN CRO PARTICLE DETECTOR FOR SOLAR PHYSICS AND SPACE WEATHER RESEARCH

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Abstract. The installation of the SEVAN CRO particle detector at Zagreb Astronomical Observatory was finished at the end of 2008. The detector is a fully autonomous unit, with the capability to send data via the Internet, and it is a part of the SEVAN (Space Environmental Viewing and Analysis Network), which includes detectors located at middle to low latitudes. Till to now the SEVAN modules are installed at Aragats Space Environmental Centre in Armenia (3 units), Bulgaria (Moussala) and Croatia (Zagreb). SEVAN detectors are use for simultaneous measurements of flux of most species of secondary cosmic rays born in the atmospheric cascade caused by primary ions and solar neutrons. These devices can be used for exploration of solar modulation effects on galactic cosmic rays. The main scientific aim is to the improve research of solar particle acceleration in the vicinity of the Sun by detecting highest energy solar cosmic rays giving additional secondaries detected by surface particle detectors and to improve researches of the space environment conditions.

Key words: SEVAN CRO - particle detector - cosmic rays

1. Introduction

The SEVAN network of particle detectors (Space Environmental Viewing and Analysis Network) aims to improve fundamental research on solar physics and space weather conditions. Ground based particle detectors measure time series of secondary particles born in cascades in the Earth's atmosphere by primary galactic cosmic rays. By detecting solar modulation effects it is possible to predict upcoming geomagnetic storms hours before the arrival of Interplanetary Coronal Mass Ejection's (ICMEs) at the space-borne instruments. Huge magnetized plasma clouds and shocks initiated by Coronal Mass Ejections (CME) travel in the interplanetary space with mean velocities up to 2500 km/sec ICME, are known as major drivers of severe space weather conditions when arriving at the Earth. On their way to Earth ICMEs also "modulate" the flux of Galactic Cosmic Rays (GCRs) introducing anisotropy and changing energy (rigidity) spectra of the previously isotropic population of protons and stripped nuclei accelerated in the numerous galactic sources. Changes in the rather stable flux of GCR are detected by space-born spectrometers (rigidities up to ∼1GV) and by world-wide networks of particle detectors (rigidities up to ∼100GV) located at different latitudes, longitudes and altitudes. The ICME is a major modulating agent, interacting with GCR, and introducing anisotropy in their flux. These anisotropies of GCR manifested themselves as peaks and deeps in time series of secondary cosmic rays, detected by surface particle detectors.

Therefore, the measurements of secondary fluxes can be used for "probing" ICMEs, providing highly cost-effective information on the key characteristics of these interplanetary disturbances. The size and magnetic field strength of ICMEs are correlated with the ICME modulation effects on the energy spectra and the direction of GCRs (Chilingarian and Bostanjyan, 2009). At the same time the presence of a strong and long-duration southward magnetic field component in the sheath region of ICMEs is the primary requirement for their geoeffectiveness (Valtonen, 2007 and references therein). Thus, the strong magnet field of the ICMEs is both the modulation agent of GCR and driver of GMS.

The large B_z value associated with approaching ICMEs is a best known diagnostics of GMS strength. Therefore, appropriate observations of the variations of the primary and secondary cosmic rays can be a proxy of B_z

value available long before IMCEs reach the L1 libration point where B_z is measured directly (see e.g., Kudela and Storini, 2006).

The ICME takes less than one hour to travel from the ACE or SOHO satellite to the magnetosphere. It is too short a time to take effective mitigation actions.

To establish a successful forecasting service by a network of ground based particle detectors we need to measure the time series of secondary particles (neutrons, low energy charged particles and high-energy muons) and to simulate and compare the correlation between changing fluxes and direction of detected particles. To meet this goal a new-type of particle detector (SEVAN detector) was designed and fabricated in Aragats Space Environmental Center (ASEC) of the Alikhanyan Physics Institute, Armenia. ASEC has a great experience with data analysis of multivariate time-series from ASEC monitors (see for example Chilingarian *et al.*, 2005; Gevorgyan *et al.*, 2005; Chilingarian *et al.*, 2003a; Chilingarian *et al.*, 2003b; Chilingarian *et al.*, 2007a; Bostanjyan *et al.*, 2007).

The SEVAN network of particle detectors is planned to be installed at middle and low latitudes and will measure secondary particles with different observational directions and different energy thresholds. The SEVAN network is compatible with currently operating neutron monitor and muon telescopes networks (Kuwabara *et al.*, 2006; Tsuchiya *et al.*, 2001; Munakata *et al.*, 2000; Mavromichalaki *et al.*, 2005; Chilingarian and Reymers, 2007b).

SEVAN modules are already installed at Aragats Space Environmental Centre in Armenia (3 units), Bulgaria (Moussala) and Croatia (Zagreb) and it is proposed to install further modules in Slovakia, Costa Rica, Indonesia and India.

2. SEVAN CRO Detector - Description and First Data

The installation of a SEVAN particle detector (SEVAN CRO) at Zagreb Astronomical Observatory (latitude 45.82 N; longitude 15.97 E; altitude 220 m; vertical cut-off rigidity 4.9 GV) was finished at the end of the year 2008. All necessary equipment, which includes scintillators, photo-multiplier tubes and electronics were provided by the Alikhanyan Physics Institute. The housing was made in Croatia. The installation was supported by the European Office of Aerospace Research and Development and the City government of Zagreb. The threshold energy of the SEVAN module was estimated

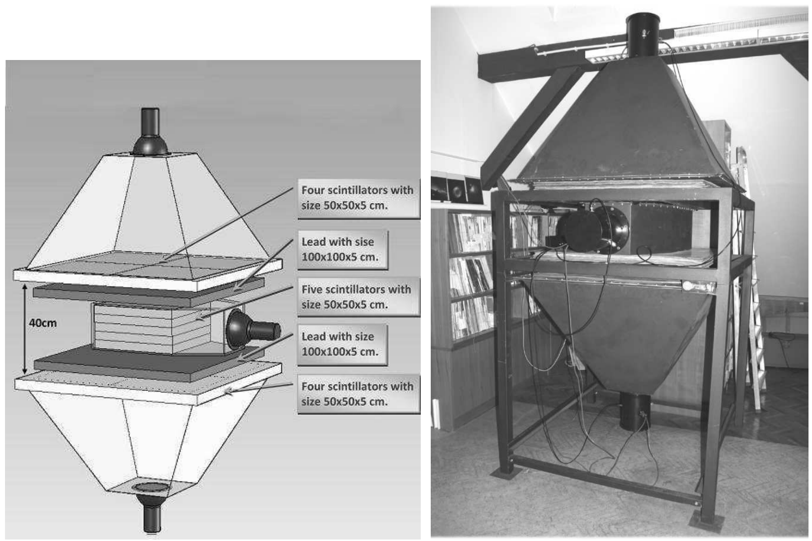

Figure 1: Particle detector SEVAN - schematic view (left) and SEVAN CRO (right)

using three different methods (Mailyan, 2009): by calculation of ionization losses of muons in lead; by computer simulation of atmospheric cascade and response of the monitor to the secondary particles and by comparing a simulated spectrum and experimentally measured count rates. Analytical calculations are in good agreement with the simulation. The selective sensitivity of the SEVAN modules allows us to probe different populations of the primary cosmic ray flux from 7 GeV to 20 - 30 GeV and to classify Ground Level Enhancements (GLEs) in neutron or proton initiated events (Chilingarian and Reymers, 2008).

A SEVAN detector is assembled from standard slabs of $50\times50\times5$ cm^3 plastic scintillators. Two identical assemblies of four slabs scintillators are separated with two lead absorbers of size $100\times100\times5$ cm^3. Between the lead absorbers there is a thick scintillator assembly of the size $50\times50\times25$ cm^3 (five standard slabs) as shown in Figure 1 (the detailed detector charts are available from http://sevan.aragats.am/). Each scintillator assembly is inside a light protected iron-made shielding with a photo-multiplier tube. So we have a 3-layer detector in which is it possible that different combinations of the signals and absence of signals occur.

If the signal appears only in the upper layer it represents the flux of low energy charged particles (mostly electrons and muons) filtered by 5 cm thick lead below the upper scintillators (energy of charged particles below 100 MeV). If we have a signal in the upper and lower layer (or in all three layers) it represents the transit of a high energy muon with minimal energy of about 250 MeV. Neutral particles undergo nuclear reactions in the 25 cm thick scintillators of the middle layer and produce protons and other charged particles. There is not enough substance in the upper 5 cm thick layer for nuclear reactions of neutral particles. If the signal appears only in the middle layer, it represents the neutral component of secondary cosmic ray fluxes. Some of the other possible combinations are when the signal appears in the upper and middle layer (transit of higher energy charged particle stopped in the second lead absorber) and when the signal appears only in the lower layer (represents inclined incidence of charged particles). SEVAN electronics (Arakelyan *et al.*, 2009) provides registration and storage of all possible combinations of the signals for further analysis. Atmospheric pressure data are collected with a pressure sensor designed and fabricated in the Yerevan Institute of Physics (Arakelyan, 2009).

One-minute measurements are stored in an output file in nine columns:

D1 - time

D2 - number of events (appearing signal) in the upper layer

D3 - number of events in the middle layer

D4 - number of events in the lower layer

D5 - atmospheric pressure

D6 - signal in the upper and middle layer (110)

D7 - signal in the upper and lower layer (101)

D8 - signal in the middle and lower layer (011)

D9 - signal in all three layers (111)

Count rates of low energy, high energy and neutral particles can be found by a simple calculation:

Low energy particles (100) = D2 - (D6 + D7 + D9)

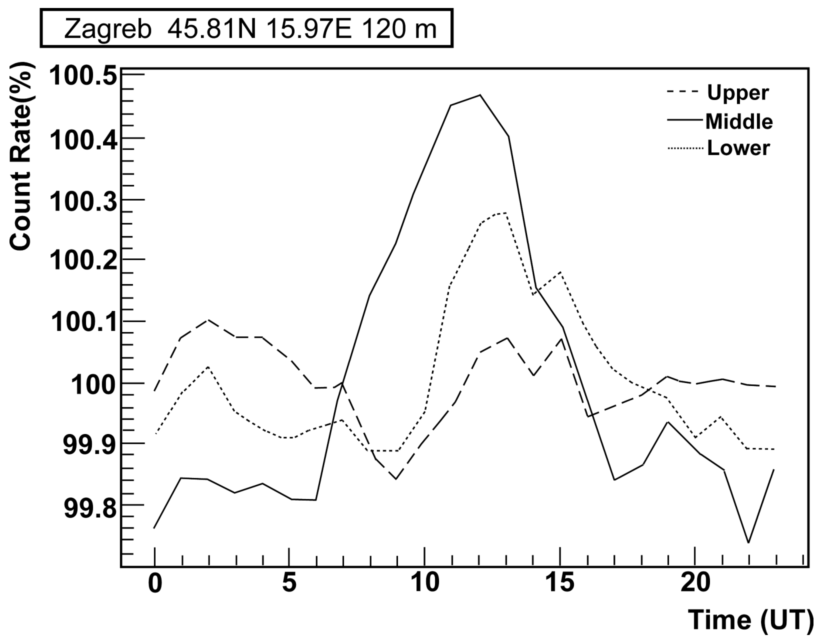

Figure 2: Daily variation of data in the upper, middle and lower layer of SEVAN CRO detector. Data are taken from December 2008-January 2009.

Neutral particles (010) = D3 - (D6 + D8 + D9)

High energy muons (111&101) = D7 + D9

The measured counting rates of different species of secondary particles by SEVAN CRO are approximately:

$6.5.10^3$ low energy charge particles (100)

3.10^3 neutral particles (010)

4.10^3 high energy muons (111&101).

As an illustration of the measurements we present (Figure 2) the daily variation in the upper, middle and lower layer of the SEVAN CRO detectors. The magnitude of variations for the upper, middle and lower layer are about 0.08%, 0.28% and 0.12% respectively and maximum appears at 14:40 LT (first of 2 equal peaks), 12:40 LT and 14:43 LT in good agreement with analogous parameters of the SEVAN network reported in Chilingarian and Mailyan, 2009. The time delay between the maxima and the magnitude of variations depends on energy of the primary cosmic ray particles.

3. Summary

The SEVAN network of middle to low latitude particle detectors started in the framework of the International Heliophysical Year and United Nations Basic Space Science projects (UNBSS) with the main aim to improve fundamental research of the solar particle acceleration mechanisms and space weather conditions. SEVAN units will be located at different latitudes, longitudes and altitudes and will measure different species of cosmic rays. The detectors are sensitive to very weak and poorly explored fluxes of high energy solar cosmic rays above 10 GeV. A SEVAN detector was installed in Zagreb Astronomical Observatory at the end of the year 2008. It is the first instrument designed for detecting cosmic rays in Croatia and its installation greatly promotes solar physics research in this country.

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